# The Airborne Snow Observatory

## The program, SnowEx 2017and future plans

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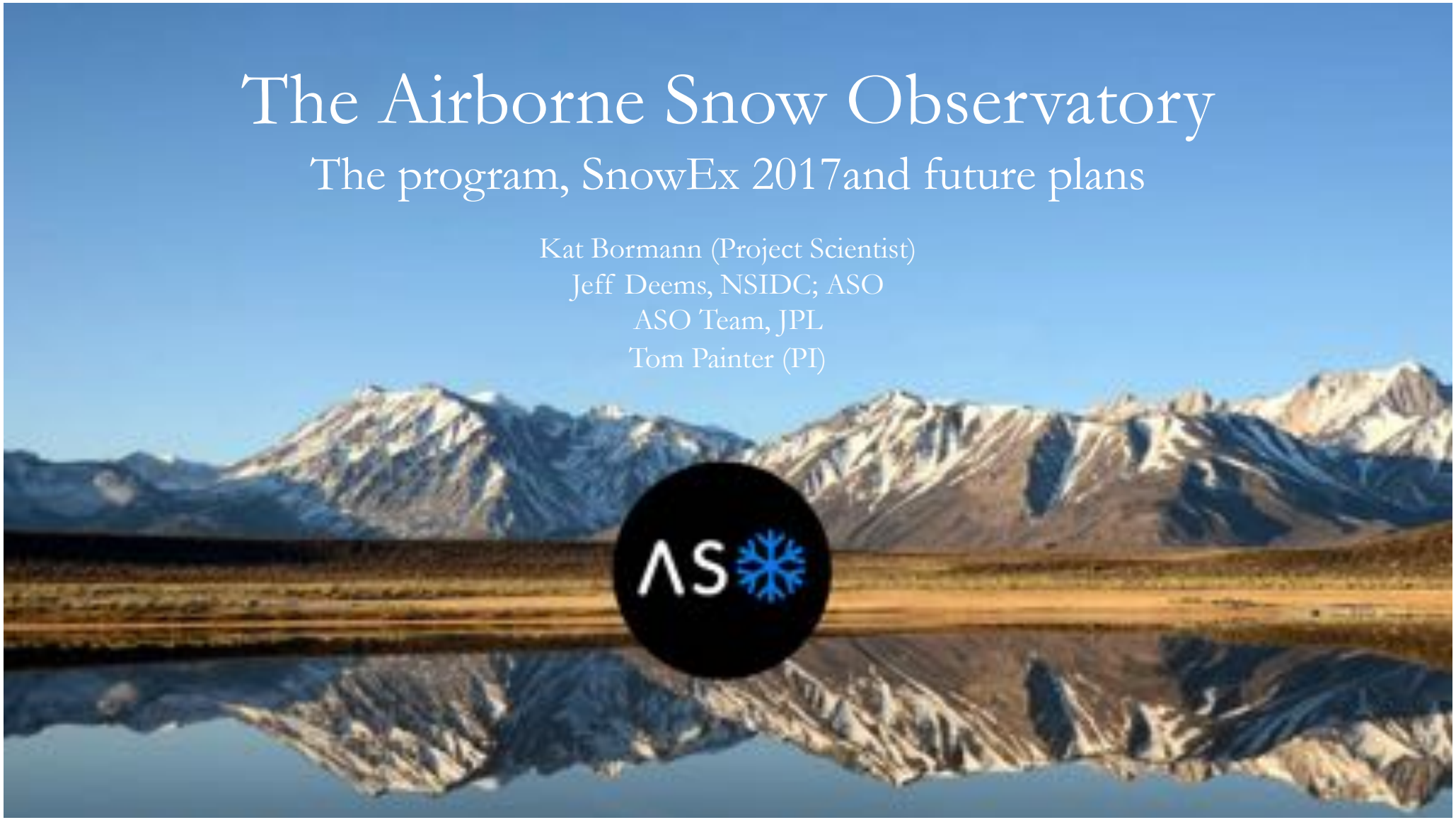

# Quick ASO Overview

GNSS/IMU – Applanix AP60
RTX GNSS correction
PPRTX Processing

Riegl Q1560 dual
laser scanning lidar
1064 nm
Full-waveform
60° field of view


CASI-1500 Imaging Spectrometer
72 bands between , 0.35 and 1.05 µm
40° field of view

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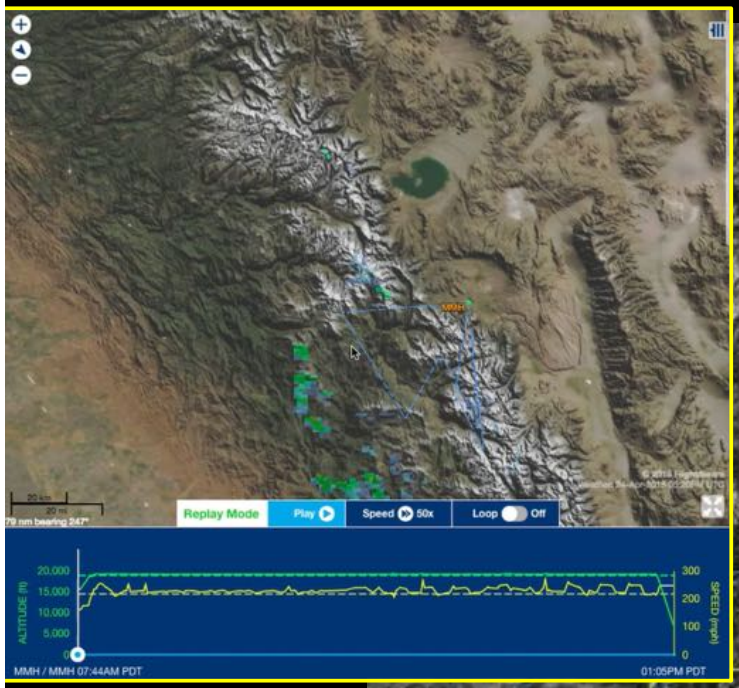


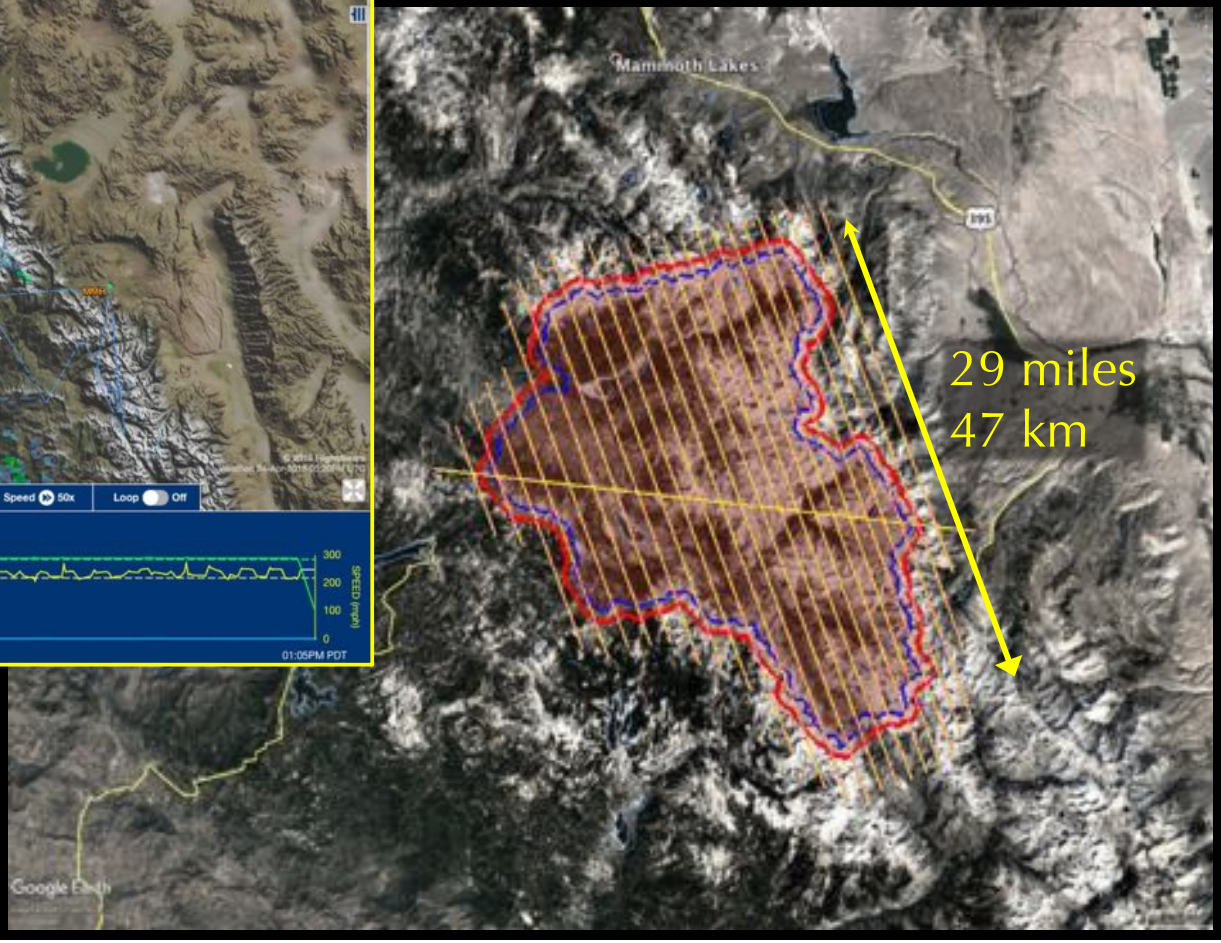


Flight operation specifics:

- Plane speed ~200 knots
- 5.5 hours max. flight endurance
- Flight altitude ~20,000 ft
- Nominal lidar point density (posting) is configurable

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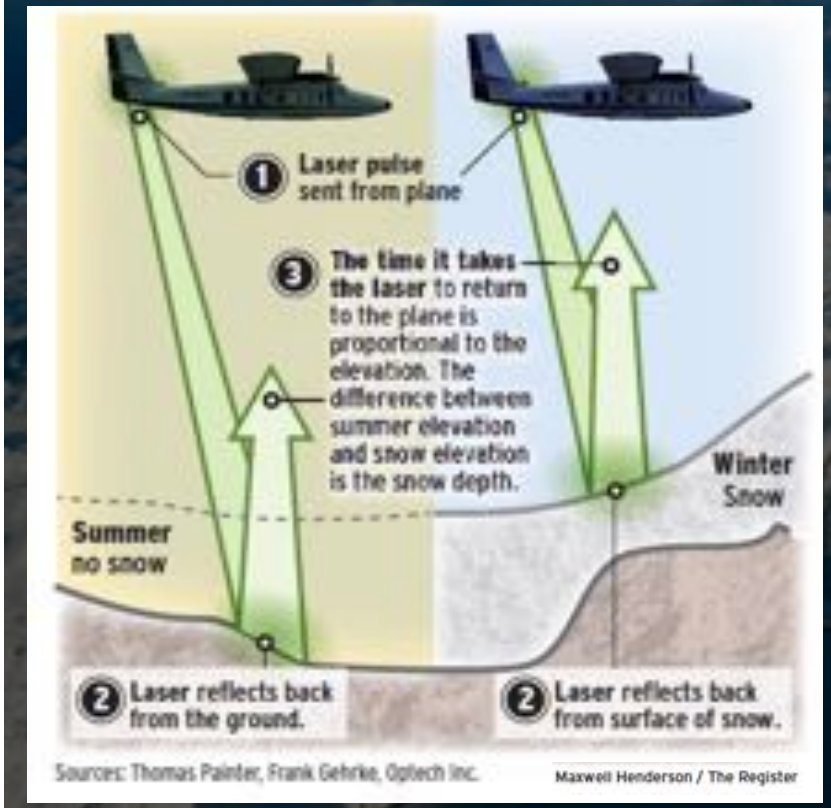
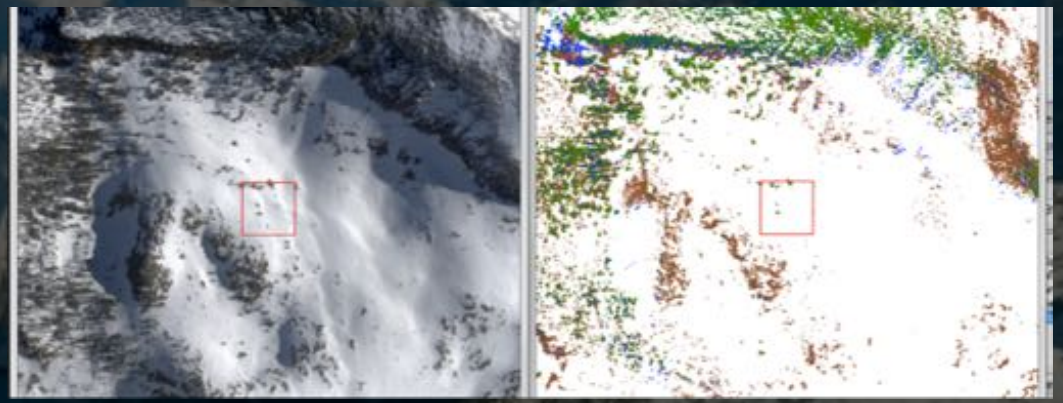



Differential technique for extracting snow depth from lidar retrievals



Guided/constrained by coincidental spectrometer information

For more information: *Painter et al. (2016), RSE*

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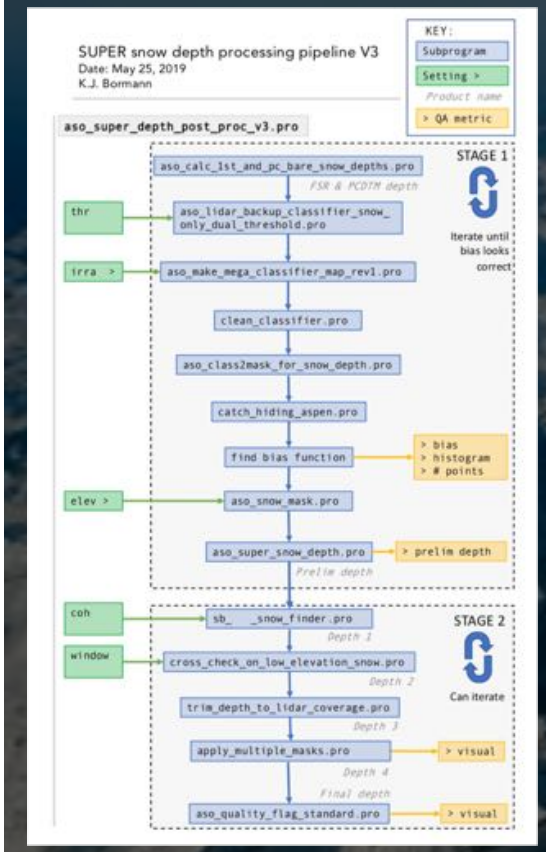


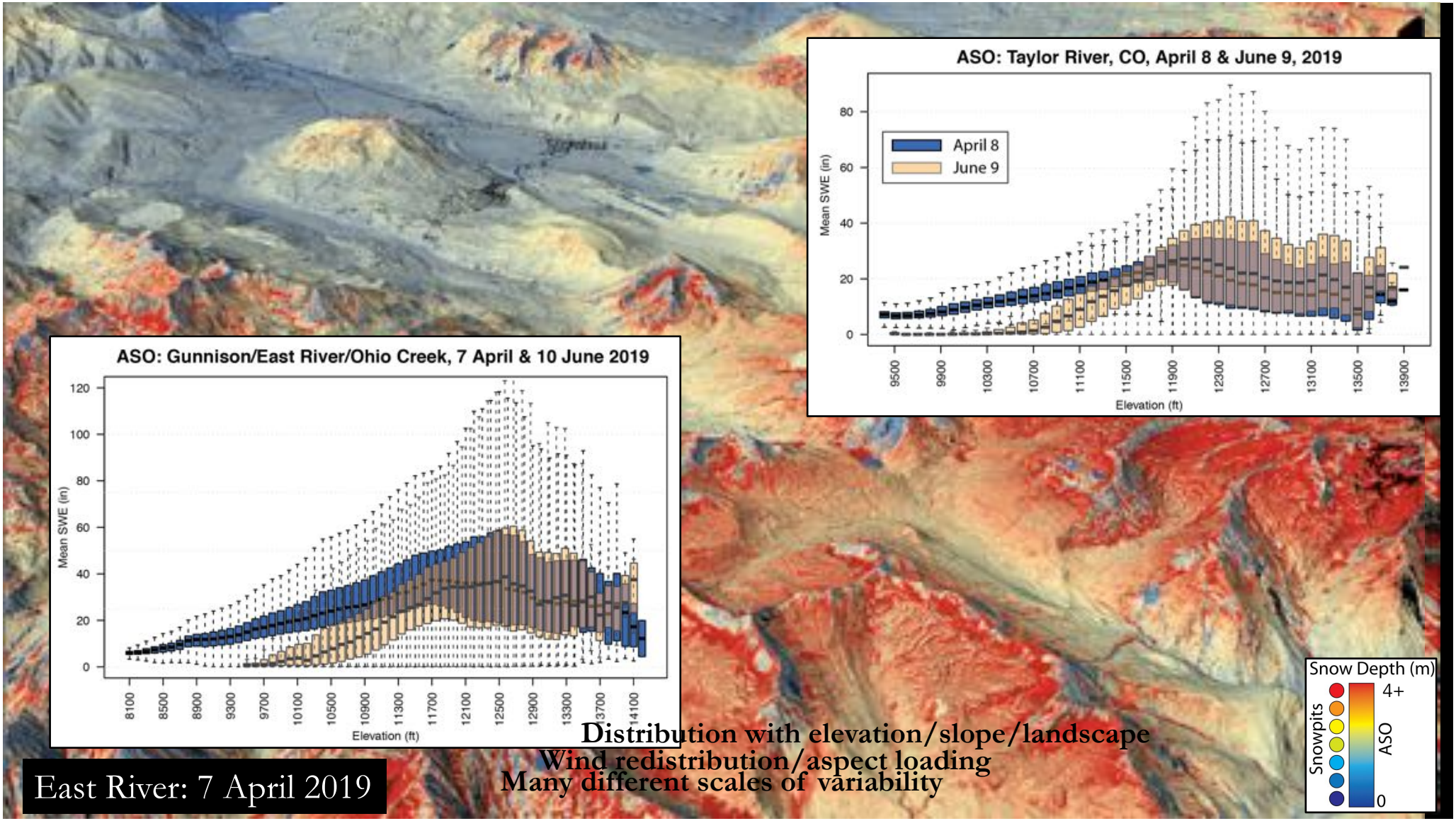

Maxwell Henderson / The Register

**It *is* that simple, but then it's <u>not</u> that simple**

Key features:

- FSR/bare elevation solutions
- Relative bias adjustment
- Intelligent CASI/lidar fusion for classification
- Knowing when to trust the lidar subtraction (and when we cannot)

For more information: *Painter et al. (2016), RSE*

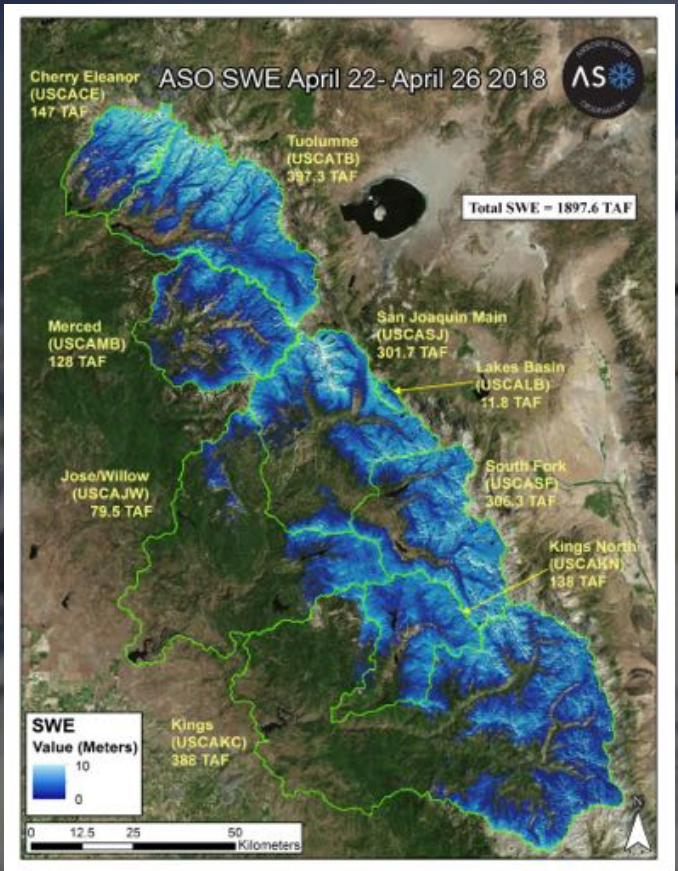



**Distribution with elevation/slope/landscape**
**Wind redistribution/aspect loading**
**Many different scales of variability**

East River: 7 April 2019

# The ASO Program

Maturing snow mapping program in California




6 core watersheds 2018-2019

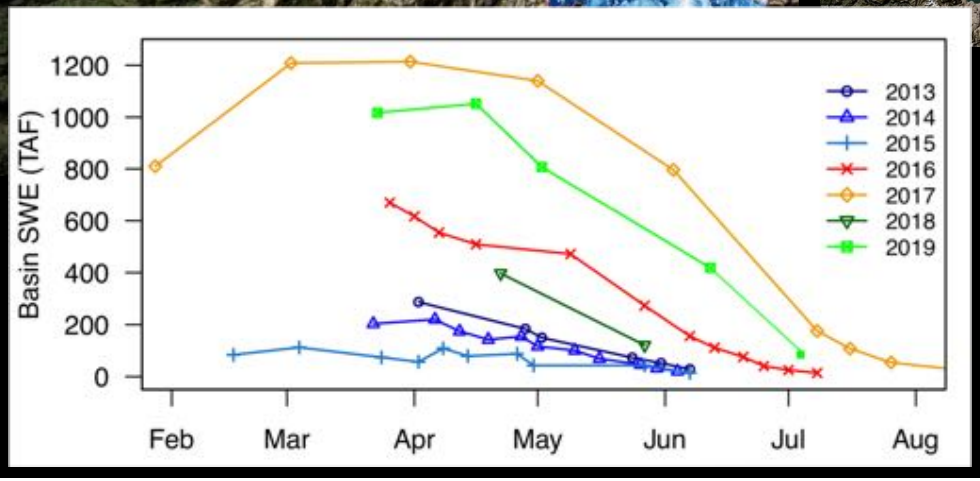
2013-2019 legacy

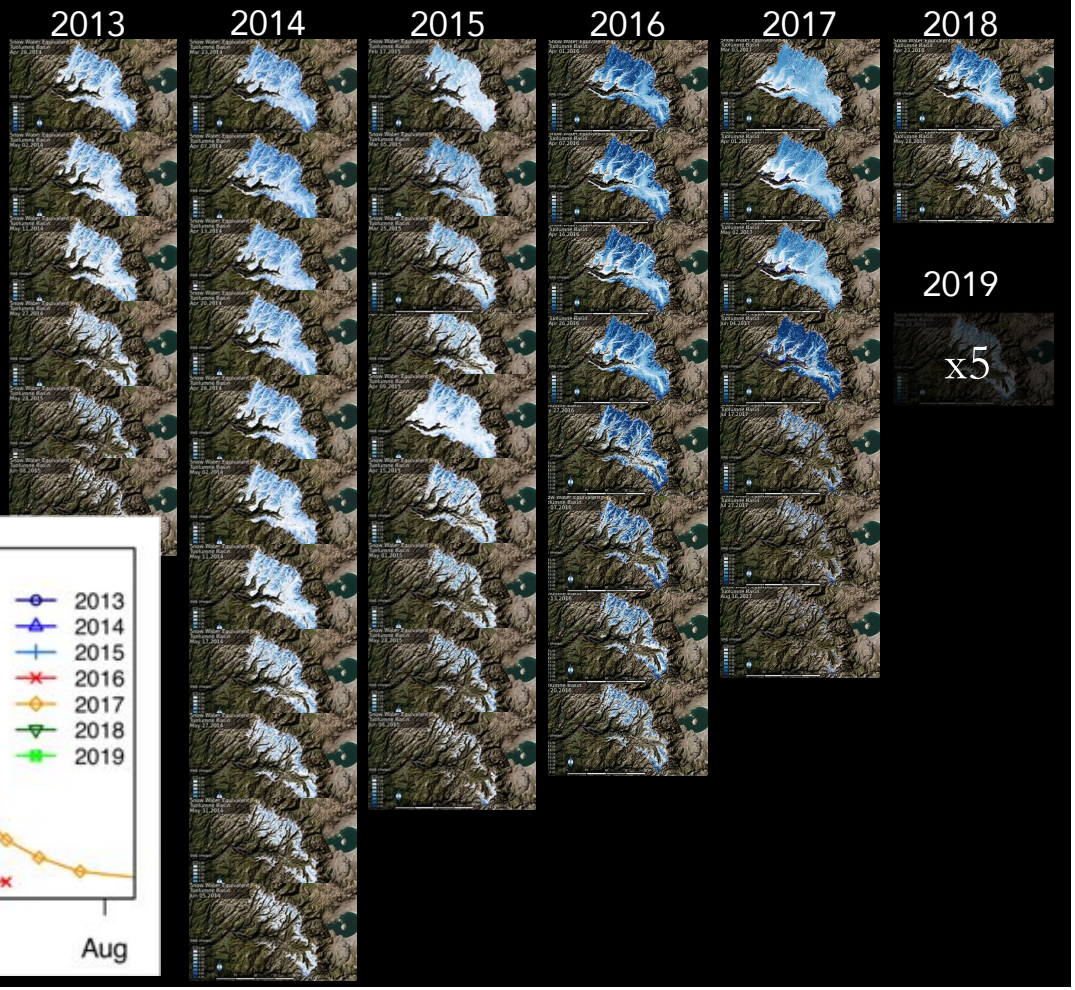
Full basin surveys 150+

Building the legacy in Colorado


3 core watersheds in 2019
Operational legacy 2019
Full basin surveys 40+

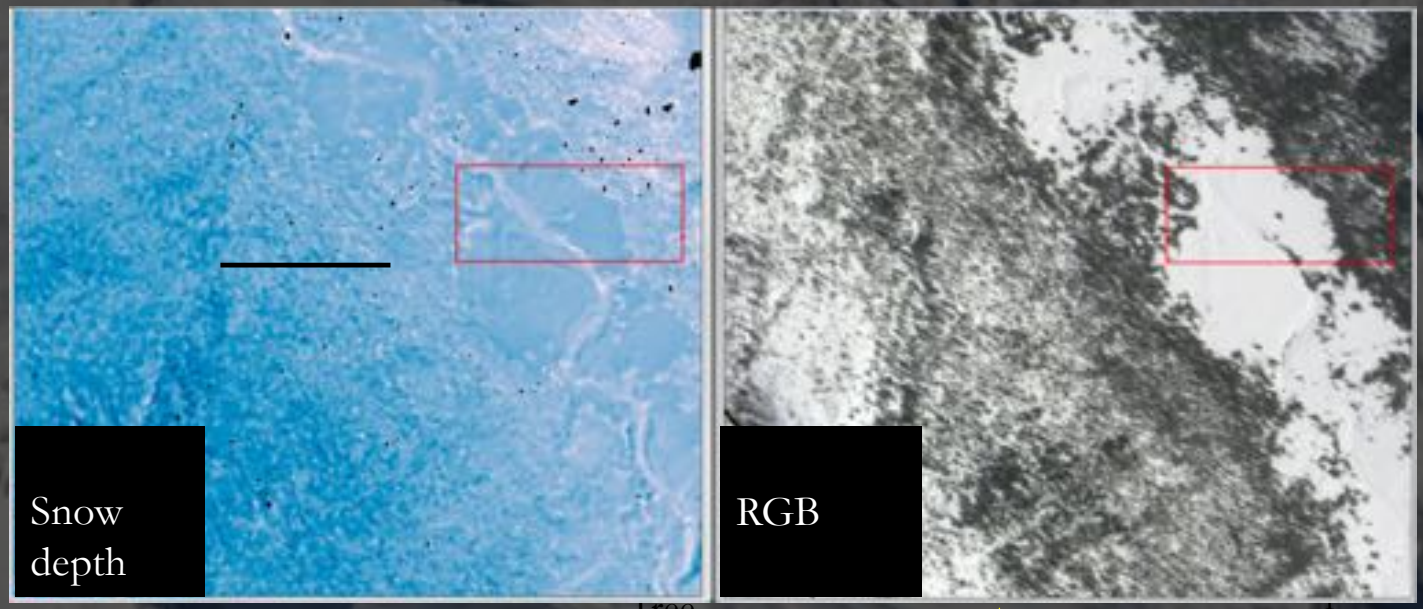
# Long-term monitoring in key basins

# 2019 upgrades

Recent algorithm upgrades that target snow depth retrieval in vegetation/ canopy



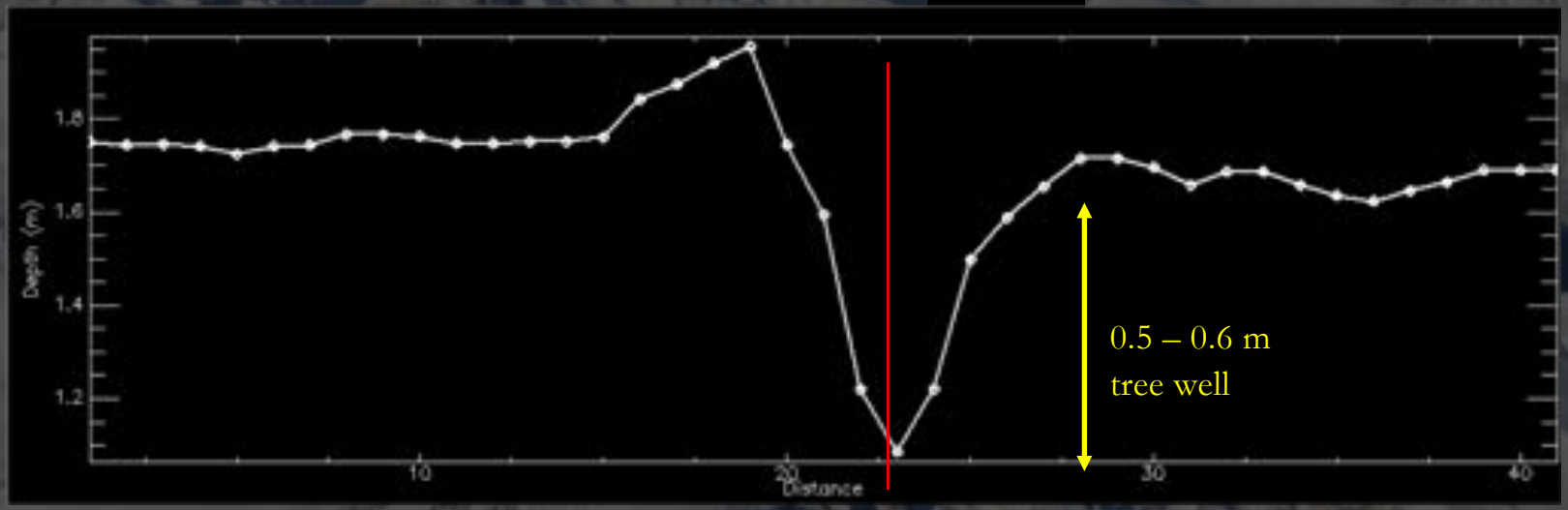
# 2019 upgrades

Recent algorithm upgrades that target snow depth retrieval in vegetation/ canopy

Snow depth

RGB

Tree well representation in the forest




We also started cloud-based processing on AWS

# What do ASO products provide?

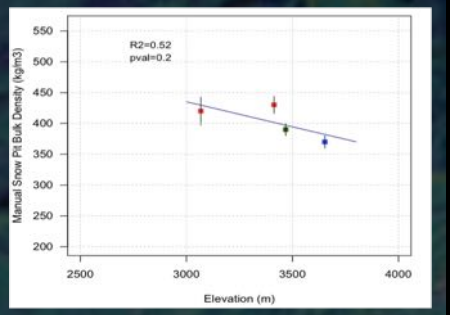
Typical ASO products provide data suitable for:

a) Quantification of total SWE volume at the watershed scale
b) Quantification of small-scale snow depth distribution (3-6 m scale)

→ 50 m SWE
→ 3 m depth

Snow density

a) For our operational basins in California we use modeled densities (constrained by in-situ) for depth to SWE conversion
b) In basins where we do not have modelling we rely on in-situ observations (pillow/course/pits) and look for opportunities to spatially distribute density

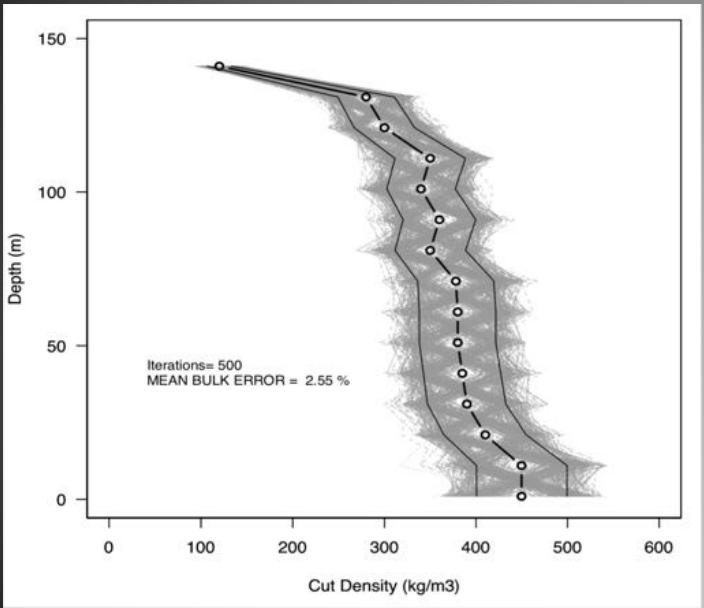



- We have very high confidence in the snow depth retrieval at the 3- 6 m scale and greater. Relative bias to the baseline DEM is almost always < 7.5 cm.
- We have found that the spatial distribution of density is a small part of the total error budget for SWE at the basin scale. We have high confidence in the basin-SWE estimates. (Measurement uncertainty ~11% [1])
- With that in mind, small-scale density in-situ or modeled estimates will be required to attain such confidence for fine-scale SWE distributions ( <50 m) from ASO. This is a great opportunity to sample density.!

# What do ASO products provide?

Following Conger & McClung (2019):

For a 1.5 m deep snow pack (spring, CA) the measurement uncertainty of 11% is reduced to ~ 2.6 % when aggregated for bulk density.



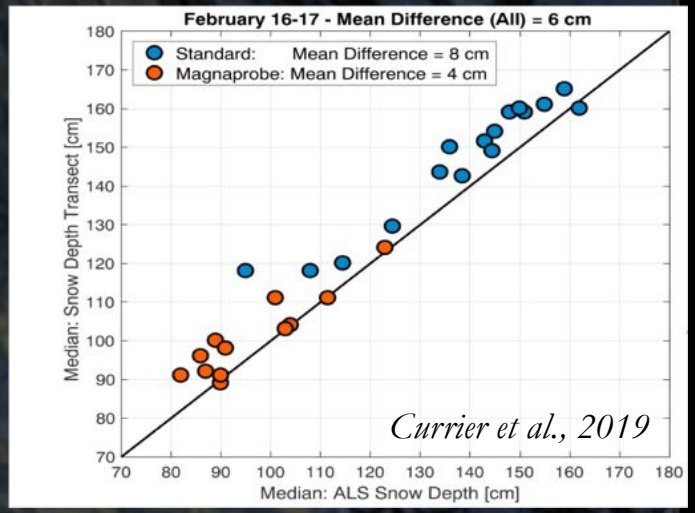

Estimated bulk density uncertainty due to measurement uncertainty

200 kg/m$^3$ ± 5 kg/m$^3$
300 kg/m$^3$ ± 8 kg/m$^3$
400 kg/m$^3$ ± 10 kg/m$^3$

# ASO and SnowEx

- Differential elevation techniques are pretty much the gold standard for high-resolution and broad extent snow depth retrieval

- ASO data can provide pivotal component of SnowEx suite, providing important context & bridging for/between other data sets.
  The data can be used:
  a) as evaluation/validation data
  b) as training data for sub-grid understanding of coarser retrieval methods
  c) to update model states
  d) to bridge the spatial gap between manual measurements
  e) to add spatial or temporal context to any other measurement collected

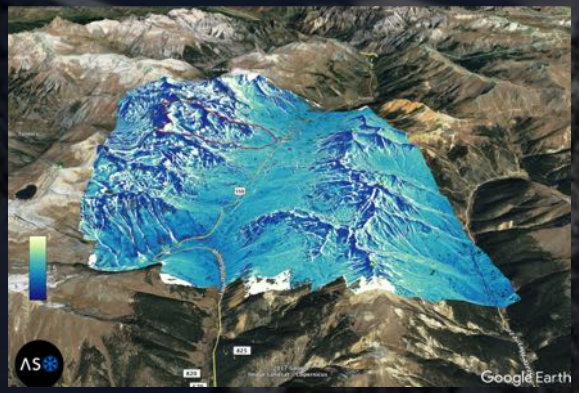


# SnowEx 2017

- 5 Grand Mesa & 5 Senator Beck Surveys
- Grand Mesa data were delivered to NSIDC
- Senator Beck data to NSIDC very soon (trajectory)

Science outcomes using SnowEx ASO collections:

1. Airborne lidar compares well with terrestrial lidar and ground measurements. *Currier et al. 2019*
2. ASO snow depth retrievals in the forest are accurate. *Mazzotti et al., 2019*
3. ASO snow depth accuracy may be sensitive to lidar point density in veg. *Patterson et al., 2017, 2018*




# SnowEx ~~2019~~ 2020

Operational ASO will be transitioning out of JPL at the end of the year.

A private company will be taking over the operational lidar surveys for water management entities in both California and Colorado

There is a still a path forward to leverage the operational ASO surveys and conduct SnowEx activities (airborne and field) in coincident with these operational survey plans:

- proposed Californian lidar surveys (1 per month starting Feb, every 2 weeks after Apr 1)
- similar operational work in Colorado is less certain, but there may also be an opportunity for 3 lidar surveys in the Blue River

SnowEx specific acquisitions are being contracted – need to ensure accurate snow depth retrieval

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